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# Studies on the Prevalence of the European Corn Borer in the East North Central States

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## INTRODUCTION

The European corn borer (*Pyrausta nubilalis* (Hbn.)), discovered in the United States in 1917 near Boston, Mass., was found for the first time in any of the East North Central States (Ohio, Michigan, Indiana, Wisconsin, Illinois, and Kentucky) in 1921, when, according to Caffrey and Worthley (*6*),[2] scouting revealed sparse infestations in most of the Ohio and Michigan townships bordering Lake Erie and on the islands in the western end of the lake. Subsequent spread of the insect from these sections to the west and south occurred until, by 1931, practically all of Ohio, much of Michigan, and the northeastern half of Indiana had become infested, and restricted infestations had appeared along Lake Michigan in Wisconsin, and south of the Ohio River in northern Kentucky. Since 1931, however,

[1] The present discussion has resulted from a study of data on the abundance of the European corn borer and some of its ecological relationships in portions of Ohio, Michigan, and Indiana, conducted by the writer from 1934 to 1939, inclusive, at Toledo, Ohio, under the direction of W. A. Baker, in charge of European corn borer research. The data used for years prior to 1934 were accumulated under the supervision of D. J. Caffrey, then in charge of European corn borer investigations. The writer is greatly indebted to Mr. Baker for his helpful interest in the study, and to K. D. Arbuthnot, an associate, for much valuable assistance in the asembly of various data during the early phases of the work.

[2] Italic numbers in parentheses refer to Literature Cited, p. 22.

further dispersion of the borer in these States has been relatively slow, and it was not until 1939 that the insect was discovered in Illinois, when five counties in the northeastern corner of the State were found infested (fig. 1).

LAKE MICHIGAN
LAKE HURON
LAKE ERIE
ONTONAGON
BARAGA
MARQUETTE
ALGER
LUCE
CHIPPEWA
MACKINAC
SCHOOL.
IRON
DICKI.
DELTA
FLOR.
FOREST
MENO.
LANGLA.
CRAWFORD
OSCODA
ALCO.
SHAWANO
OUTA.
BROWN
KEWAUNEE
WAUS.
CAL.
MANI.
WEX.
MISS.
ROSC.
OGE.
IOSCO
MAS.
LAKE
OSCE.
CLAR.
GLAD.
ARENAC
HURON
OCEA.
NEWA.
MECO.
ISAB.
MID.
BAY
MONTCA.
GRAT.
SAGINAW
TUSCO.
SANIL.
MUS.
OTTA.
KENT
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CLIN.
SHIA.
GENE.
LAP.
ST.CL.
ALLEG.
BAR.
EAT.
INGH.
LIVIN.
OAKL.
MAC.
LAMBTON
MIDDLESEX
OXFORD
ELGIN
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PERTH
WATER.
WELL.
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KAL.
CALH.
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LUCE
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ERIE
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CUYAH.
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MEDIN.
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WAYNE
STARK
COLUM.
HOLM.
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LICKING
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GREEN.
LAW.
LEWIS

Field observations to determine the relative abundance of the corn borer were begun in Ohio and Michigan in 1925 and in Indiana in 1928, and in these and succeeding years surveys of various character and extent have been conducted each fall by the Bureau of Entomology and Plant Quarantine.[3] The need for efficient survey methods led to a study of the problem by several workers of the Bureau, and the consequent development of a standardized procedure which proved a practical way of obtaining adequate comparable data on annual fluctuations in borer abundance. Over the 13-year period 1927–39 comparable data on the abundance of the European corn borer were collected each fall in a section comprising 18 counties in southeastern Michigan and northwestern Ohio to the westward of Lake Erie, and these have provided the basis for studying fluctuations of the insect's abundance in relation to weather factors operative over the region during these years.

In the years 1927–29, 5 cornfields were examined within each township of a surveyed county, and the data for an individual field were based on a count of 500 plants for infestation and a dissection of 10 infested plants to determine the number of borers per plant attacked by the insect. Beginning in 1930, the fields were located at random over each county surveyed, the number per county ranging from 23 to 98 in 1930 and from 20 to 25 in 1931, 1932, and 1933. Twenty fields were surveyed within a county in each of the years 1934–38, the procedure in each field consisting of a count of 100 plants for infestation and the dissection of 10 infested plants to determine the number of borers per infested plant. In 1939, 25 corn plants were examined for infestation and 2 infested plants dissected in each field. The resultant data in all years were presented on the basis of number of borers per 100 plants. Climatological data published by the Weather Bureau were used freely in the course of study.

In addition, a series of intensive observations on the seasonal development of the corn borer during the 6-year period 1934 to 1939, inclusive, was conducted at Toledo, Ohio, with the hope of determining and evaluating more definitely the most important factors responsible for annual fluctuations in abundance of the insect.

In the case of the European corn borer, as with many other insects, it has been difficult to express quantitatively the association of abundance of the insect with weather factors. Numerous leads which appeared promising at one time or another, or for a certain series of years, later lost their significance in the light of more extensive data. Nevertheless the evidence continues to point to meteorological conditions, acting either directly or indirectly, as the most important influence affecting populations of the corn borer. It is possible that the ultimate answer to the problem can be obtained only by some entirely different approach, or it may be that significant correlations can be determined only by the accumulation of such a mass of detailed intensive data on populations of the borer and weather factors that, as a practical procedure, the end would not justify the means.

Although each year's data add to the accumulated knowledge and better understanding of the corn borer's relation to its environment, it is felt that the time has come for a review of the investigation to date and the presentation of whatever interpretations are now possible.

[3] The survey work in Indiana for a number of years has been largely supported by the State Conservation Department of Indiana.

## FIELD STATUS OF THE CORN BORER, 1934–39

To depict the more recent status of the European corn borer in Ohio, Michigan, and Indiana, where the insect has been more prevalent than in any of the other of the East North Central States, a brief review is offered of the facts determined by field surveys in the years 1934–39. Table 1 presents comparable data on borer abundance in the three States for the 6-year period.

TABLE 1.—*Relative abundance of the European corn borer in Ohio, Michigan, and Indiana, 1934–39*

| State | Counties or county groups | 1934 | | 1935 | | 1936 | | 1937 | | 1938 | | 1939 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fields surveyed | Borers per 100 plants | Fields surveyed | Borers per 100 plants | Fields surveyed | Borers per 100 plants | Fields surveyed | Borers per 100 plants | Fields surveyed | Borers per 100 plants | Fields surveyed | Borers per 100 plants |
| | | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* |
| Ohio | 12 counties | 240 | 16.4 | 240 | 44.4 | 240 | 70.8 | 240 | 72.9 | 240 | 133.0 | 120 | 108.7 |
| Michigan | 6 counties | 120 | 14.0 | 120 | 38.2 | 120 | 68.0 | 120 | 151.1 | 120 | 122.7 | 60 | 162.0 |
| Indiana | 3 county groups | 120 | 3.5 | 120 | 12.0 | 120 | 4.2 | 120 | 5.3 | 222 | 49.1 | 225 | 98.9 |
| Average | | ----- | 12.6 | ----- | 34.8 | ----- | 53.5 | ----- | 75.6 | ----- | 98.9 | ----- | 111.2 |

In the surveyed portion of infested territory in Ohio, Michigan, and Indiana there was a general decrease in borer infestation in 1934 [4] from that found in either 1932 or 1933. Increases in 1934 over 1933 appeared in only 1 county and 2 county groups out of 23 units surveyed in these States. In the remainder there occurred a decrease or no appreciable change in borer populations. The level of borer population in 1934 was relatively low, not exceeding an average of 48 borers per 100 plants in any county of the 3 States. The heaviest infestation occurred in a limited region of Ohio and Michigan extending a short distance southwestward from the western end of Lake Erie. In Indiana the chief concentration of borer population was in the extreme northeastern corner of the State.

A very definite increase in corn borer infestation occurred in 1935 [5] over that of 1934 in southeastern Michigan, in the northwestern quarter of Ohio, and in northeastern Indiana, in decided contrast to the decrease in 1934 as compared with 1933. The territory in Michigan, Ohio, and Indiana that showed an increase in 1935 over 1934 comprised 50 (or 67.6 percent) of the 74 counties surveyed in that part of the area. In 19 of the other counties included, the 1935 survey revealed no change in the corn borer population from that of the previous year, and in 1 group of 5 counties in northeastern Ohio there was a decrease in infestation. In northwestern Ohio half the counties surveyed fell within a zone of increase. As in previous years, the most heavily infested district in 1935 seemed to follow the old lake-bottom land in a southwestward direction from the western end of Lake Erie, while relatively light infestation continued in the eastern portion of

[4] VANCE, A. M. REPORT ON STATUS OF THE EUROPEAN CORN BORER IN 1934. U. S. Bur. Ent. and Plant Quar. report issued December 1934. 9 pp., illus. [Processed.]

[5] VANCE, A. M. REPORT ON STATUS OF THE EUROPEAN CORN BORER IN 1935. U. S. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 15: 423–431, illus. [Processed.]

the surveyed part of the State. In Michigan the most outstanding increase of the borer in 1935 occurred in the northern portion of the section known as the "thumb," and in Indiana the most significant increase was found in the extreme northeastern counties of the State.

There was a significant increase in the number of borers per 100 plants in 1936[6] over 1935 in Michigan, Ohio, and Indiana, as a whole, due principally to increases, and trends toward increase, in the northwestern corner of Ohio and the southeastern part of Michigan, west of Lake Erie. On the other hand, definite decreases in infestation in 1936, as compared with 1935, occurred in eastern Indiana, in the lower two-thirds of the region surveyed in the western half of Ohio, and in the "thumb" section of Michigan, resulting in a reduction of populations in these regions to the level of 1934, with a practical elimination of the gain that had been made in 1935. Corn borer infestation in 1936 was most intense west and south of the western end of Lake Erie. An extension of the 1936 survey showed the borer to be present in negligible numbers in central Indiana and in the southwestern corner of Michigan. In parts of central Michigan, however, the pest was practically as abundant as in some of the older infested counties in the eastern section of the State.

As reported by Baker and Vance (*4*), the European corn borer in the surveyed portions of Michigan, Ohio, and Indiana, taken as a whole, was as generally distributed and as abundant in 1937 as in any previous year of record. A definite increase in corn borer abundance in 1937 over 1936 was shown along the southeastern edge of Michigan. In the surveyed parts of northwestern Ohio the status of the insect in 1937 remained about the same as in 1936, with a significant increase in population in 1937 over 1936 in four counties and one county group and no appreciable change in the remaining eight counties surveyed in the State. The Indiana region surveyed in 1937, comprising three county groups in the northeastern corner of the State, had about the same low population level as in 1936.

In 1938[7] the general trend of corn borer abundance in Michigan, Ohio, and Indiana was toward an increase over the 1937 season. Although the average population in some counties on the western end of Lake Erie showed little change, and even decreased in several counties in southeastern Michigan, the average borer population in the surveyed portions of Michigan and Ohio (including principally the oldest infested counties of these States) reached the highest level recorded for this section to date. Increases in populations of the corn borer in 1938 over 1937 were particularly pronounced in six counties in the extreme northwestern corner of Ohio, where the insect occurred in greater numbers than at any previous time. Similar conditions prevailed in Indiana where, while the general borer level was low as compared with older infested areas in Ohio and Michigan, populations of the insect in 1938 were higher than found in any previous survey.

Within that portion of Michigan, Ohio, and Indiana for which comparable data are available for both 1938 and 1939 there was a significant increase in abundance of the corn borer in the latter over

[6] VANCE, A. M. REPORT ON THE STATUS OF THE EUROPEAN CORN BORER IN 1936. U. S. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 16: 429–436, illus. [Processed.]

[7] BAKER, W. A., and VANCE, A. M. RELATIVE ABUNDANCE OF THE EUROPEAN CORN BORER IN 1938. U. S. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 18: 643–647, illus. [Processed.]

the former year.[8] Although the infestation in 12 counties of northwestern Ohio remained about the same for these 2 years, significant increases in 1939 over 1938 took place in the 35 counties of northeastern Indiana and 6 counties of southeastern Michigan included in the survey. A survey in 1939, more extensive than in any of the other years under consideration, showed that in several counties near the central part of western Ohio the populations of the borer had built up to equal or even exceed those present for a number of years in some of the older-infested counties near the end of Lake Erie. Abundance of the corn borer was relatively low (averaging less than 67 borers per 100 plants) in 30 counties surveyed in 1939 in the eastern half of Ohio. Huron County in Michigan, with its average of 595 borers per 100 plants, was the most heavily infested county in the East North Central States in 1939.

## INTENSITY OF INFESTATION

Infestations of the European corn borer, as in the case of certain other insects, have been more chronic and consistently of greater economic importance in some localities or sections than in others, both in Europe and in the United States. For the present study the general intensity of corn borer infestation from 1927 to 1938, inclusive, in the Michigan-Ohio section under consideration has been indicated in figure 2 from data taken during fall surveys of abundance; and detailed data on the abundance of the borer in this section, collected each fall over the same period of years with 1939 added, are given in table 2. The section in which survey data were obtained is composed of 6 counties in southeastern Michigan and 12 in northwestern Ohio, to the west of Lake Erie, as shown in figures 1 and 2.

TABLE 2.—*A 13-year comparison of populations of the European corn borer in 18 comparable counties in Michigan and Ohio, 1927–39*

| State and county | Average borers per 100 plants | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1927 | 1928 | 1929 | 1930 | 1931 | 1932 | 1933 | 1934 | 1935 | 1936 | 1937 | 1938 | 1939 | 1927–39 |
| Michigan: | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* | *No.* |
| Lenawee | 1.4 | 10.1 | 21.7 | 34.3 | 32.9 | 50.0 | 32.0 | 13.3 | 56.4 | 53.6 | 147.9 | 206.4 | 118.8 | 59.9 |
| Macomb | 38.2 | 50.8 | 32.2 | 39.5 | 21.5 | 72.6 | 16.4 | 20.9 | 45.9 | 43.2 | 178.6 | 191.2 | 132.8 | 68.0 |
| Monroe | 72.0 | 52.9 | 84.0 | 16.1 | 42.7 | 72.7 | 62.8 | 27.6 | 42.9 | 98.0 | 215.9 | 124.8 | 240.0 | 88.6 |
| St. Clair | 138.4 | 44.6 | 18.7 | 25.7 | 22.7 | 20.8 | 15.7 | 11.8 | 57.3 | 69.4 | 157.7 | 74.4 | 197.0 | 65.7 |
| Washtenaw | .6 | 2.7 | 14.1 | 4.4 | 10.8 | 49.7 | 16.4 | 2.7 | 19.5 | 45.4 | 75.4 | 73.2 | 167.6 | 37.1 |
| Wayne | 62.7 | 17.8 | 13.1 | 12.7 | 61.3 | 59.7 | 35.8 | 7.7 | 7.2 | 98.6 | 131.0 | 65.9 | 116.0 | 53.3 |
| Ohio: | | | | | | | | | | | | | | |
| Defiance | .1 | .4 | .9 | 5.6 | 15.9 | 12.8 | 12.6 | 8.1 | 4.8 | 11.0 | 27.5 | 190.7 | 35.0 | 25.0 |
| Fulton | 2.9 | 4.8 | 21.2 | 16.1 | 29.8 | 46.2 | 53.7 | 30.1 | 41.0 | 63.9 | 67.1 | 272.3 | 91.8 | 57.0 |
| Hancock | .4 | 1.8 | 26.9 | 8.6 | 56.9 | 53.8 | 36.5 | 25.9 | 38.8 | 96.6 | 66.8 | 127.9 | 182.6 | 55.7 |
| Henry | .8 | 2.0 | 7.8 | 26.3 | 36.3 | 52.7 | 58.8 | 10.4 | 44.7 | 74.2 | 66.4 | 188.8 | 120.0 | 53.0 |
| Lucas | 18.2 | 40.4 | 132.1 | 30.2 | 53.8 | 49.8 | 181.2 | 22.7 | 121.5 | 161.5 | 149.4 | 212.3 | 191.0 | 104.9 |
| Ottawa | 29.5 | 45.5 | 96.3 | 45.4 | 55.8 | 49.7 | 70.7 | 22.5 | 25.9 | 86.9 | 99.9 | 41.6 | 65.4 | 56.5 |
| Paulding | 0 | .1 | .9 | 2.5 | 10.4 | 30.5 | 6.5 | 3.0 | 42.1 | 10.6 | 31.4 | 77.1 | 105.4 | 24.7 |
| Putnam | .2 | .7 | 7.4 | 6.1 | 51.4 | 48.0 | 15.0 | 3.1 | 37.6 | 52.1 | 45.7 | 40.2 | 211.6 | 39.9 |
| Sandusky | 10.9 | 18.2 | 21.2 | 14.0 | 78.0 | 66.3 | 71.7 | 3.8 | 48.6 | 107.1 | 89.3 | 104.3 | 80.0 | 54.9 |
| Seneca | 1.4 | 5.3 | 30.8 | 5.8 | 69.4 | 46.6 | 6.5 | 16.7 | 27.9 | 31.8 | 101.8 | 81.8 | 35.0 | 35.4 |
| Williams | 1.6 | 1.7 | 3.3 | 9.0 | 8.9 | 27.1 | 34.1 | 2.5 | 9.2 | 15.4 | 33.1 | 136.5 | 35.6 | 24.5 |
| Wood | 3.4 | 7.5 | 55.2 | 8.3 | 71.6 | 66.5 | 92.5 | 47.6 | 91.2 | 138.4 | 96.4 | 122.3 | 151.2 | 73.2 |
| Average | 21.3 | 17.1 | 32.7 | 17.3 | 40.7 | 48.6 | 45.5 | 15.6 | 42.4 | 69.9 | 99.0 | 129.5 | 126.5 | 54.3 |

[8] VANCE, A. M. STATUS OF THE EUROPEAN CORN BORER IN 1939. U. S. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. 19: 603–618, illus. [Processed.]

The procedure used to indicate the relative abundance of the corn borer over the section (fig. 2) was to average the population data for all cornfields surveyed in each township over the 12-year period of

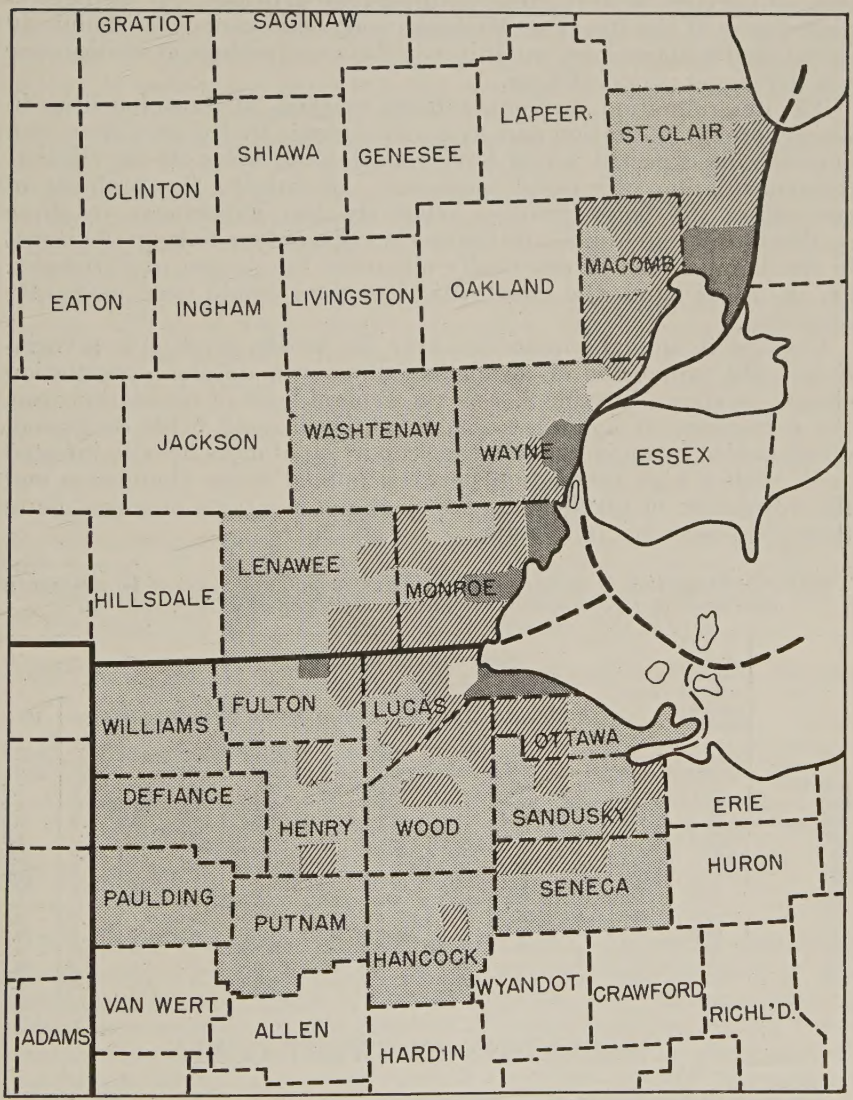


FIGURE 2.—Relative abundance of the European corn borer over the period 1927–38 in a section comprising 18 counties in Ohio and Michigan. In the localities most heavily shaded the average number of borers per 100 corn plants exceeded 100, in those with medium shading the average was between 50 and 100, and in the most lightly shaded portions it was less than 50.

study. Although subject to the error involved in the averaging of different numbers of fields per township or particular year, the presentation is the best possible with the data in hand. During the years 1927–38, however, the insect had probably not reached a state

of equilibrium over the entire section, and it is very likely that other points of chronic infestation will appear in the future. Peculiar environmental complexes presumably account for the greater prevalence of the corn borer in some localities than in others, but the permanent status of the insect in Michigan and Ohio cannot be definitely established without more quantitative data and ecological studies over a much longer period of time.

The determination, by some reliable method, of those localities in which chronic infestation and economic damage by the corn borer can normally be expected would have considerable value in the efficient recommendation of control measures. Obviously, the problem of controlling the borer assumes relatively less importance in those sections where environmental factors are of a nature to keep the insect in check and lessen or practically eliminate the danger of outbreaks. On the other hand, the more critical sections would need particular attention.

Changes in annual populations over the section resulted in a variation in the proportion of cornfields falling into different population classes, as shown in table 3. As the general level of infestation rose, the percentage of noninfested and lightly infested fields decreased, accompanied by an increase in the proportion of more heavily infested ones, with a high correlation between annual borer abundance and the proportion of cornfields in which the populations averaged more than 100 borers per 100 plants.

TABLE 3.—*Proportion of cornfields with different population levels of the European corn borer in 18 comparable counties in Michigan and Ohio, 1927–39*

| Year | Average borers per 100 plants | Fields | Fields with indicated number of borers per 100 plants | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1–10 | 11–50 | 51–100 | 101–200 | 201–300 | 301–400 | 401–500 | 501+ | 101+ |
| | *Number* | *Number* | *Per-cent* | *Per-cent* | *Per-cent* | *Per-cent* | *Per-cent* | *Per-cent* | *Per-cent* | *Per-cent* | *Per-cent* | *Per-cent* |
| 1927 | 21.3 | 1,250 | 30.4 | 45.2 | 13.6 | 3.5 | 4.0 | 0.8 | 1.3 | 0.6 | 0.6 | 7.3 |
| 1928 | 17.1 | 1,318 | 15.2 | 56.4 | 19.1 | 5.3 | 2.6 | 1.2 | .1 | .1 | ------ | 4.0 |
| 1929 | 32.7 | 446 | 10.8 | 46.4 | 25.6 | 7.8 | 5.6 | 2.5 | .9 | .2 | .2 | 9.4 |
| 1930 | 17.3 | 877 | 5.6 | 53.0 | 35.5 | 4.8 | 1.1 | ------ | ------ | ------ | ------ | 1.1 |
| 1931 | 40.7 | 405 | 5.2 | 26.2 | 41.7 | 16.1 | 8.7 | 1.5 | .2 | .2 | .2 | 10.8 |
| 1932 | 48.6 | 370 | 9.7 | 22.2 | 37.9 | 15.1 | 12.2 | 1.9 | .5 | 0 | .5 | 15.1 |
| 1933 | 45.5 | 375 | 22.7 | 28.5 | 27.5 | 10.7 | 5.6 | 1.8 | 1.3 | .8 | 1.1 | 10.6 |
| 1934 | 15.6 | 360 | 19.7 | 42.5 | 31.1 | 5.3 | 1.1 | .3 | ------ | ------ | ------ | 1.4 |
| 1935 | 42.4 | 360 | 5.5 | 27.5 | 36.1 | 21.4 | 7.8 | 1.1 | .3 | 0 | .3 | 9.5 |
| 1936 | 69.9 | 360 | 3.3 | 23.6 | 32.8 | 16.9 | 15.6 | 4.7 | 1.4 | 1.1 | .6 | 23.4 |
| 1937 | 99.0 | 360 | 4.7 | 10.8 | 30.3 | 20.3 | 20.3 | 8.1 | 2.2 | 1.9 | 1.4 | 33.9 |
| 1938 | 129.5 | 360 | 3.9 | 7.8 | 21.7 | 21.9 | 24.2 | 12.5 | 3.9 | 1.9 | 2.2 | 44.7 |
| 1939 | 126.5 | 180 | 6.6 | 7.2 | 22.8 | 22.8 | 20.0 | 10.0 | 5.0 | 2.8 | 2.8 | 40.6 |

## INFESTATION IN SWEET CORN

Limiting a discussion of the abundance of the corn borer in Michigan, Ohio, and Indiana to data procured during surveys in the fall of each year omits from the picture the importance of the insect as a pest of early-market sweet corn. From 1934 to 1938, inclusive, the European corn borer was increasingly destructive to early-market sweet corn grown in a trucking area west of Toledo, Ohio, and in 1939, although the damage to the crop in this locality was less severe than in 1938, sufficiently large populations of the insect were present to cause grave concern to the grower. In recent years, also, there was

evidence that the insect might approach economic importance in early sweet corn for market or canning purposes in other sections of northern Ohio, southeastern Michigan, and central Indiana.

Data on corn borer infestation in early sweet corn must be taken in midsummer near the period of harvest in July, as many of the fields planted to this crop are eliminated by the time of the fall infestation survey or only rarely enter into the random sampling procedure utilized. Although the method followed in surveying each field of sweet corn in the summer has been the same as that used generally in the fall survey, the fields of sweet corn examined were selected because they were the earliest or most heavily infested in the locality, and not on a random basis, the objective in this case having been to determine the maximum economic importance of the borer in this particular crop within a given locality.

Surveys of corn borer infestation in early-market sweet corn in the locality of Toledo, Ohio, made on the above basis in each of the years 1934 to 1939, inclusive, resulted in the data summarized in table 4. In addition, it was determined that in 1938 populations of the borer averaged 1,128 per 100 plants in 8 fields of early sweet corn examined in Erie-Huron counties, Ohio; 66 per 100 plants in 10 fields in Cuyahoga-Lorain counties, Ohio; and 285 per 100 plants in 10 fields in Wayne County, Mich. Only 9 borers per 100 plants were found in a survey of 20 fields in the last-named county in 1935. In 1938, when the most severe damage occurred in sweet corn near Toledo, practically 100 percent of the plants were infested. Only 2 of the 25 fields surveyed that year averaged less than 1,000 borers per 100 plants and 6 of the fields averaged 2,000 or more borers per 100 plants.

TABLE 4.—*Abundance of the European corn borer in early-market sweet corn near Toledo, Ohio, 1934–39*

| Year | Fields surveyed | Plants infested | Average borers per 100 plants | Year | Fields surveyed | Plants infested | Average borers per 100 plants |
|---|---|---|---|---|---|---|---|
| | *Number* | *Percent* | *Number* | | *Number* | *Percent* | *Number* |
| 1934 | 15 | 73.4 | 268 | 1937 | 25 | 89.8 | 794 |
| 1935 | 25 | 67.2 | 328 | 1938 | 25 | 99.4 | 1,751 |
| 1936 | 25 | 88.0 | 469 | 1939 | 25 | 96.6 | 817 |

It is possible that the increasing prevalence of a second generation of the corn borer in the Lake States, as discussed elsewhere in this circular, and particularly in central Indiana, may increase appreciably the magnitude of the problem of controlling the pest in sweet corn in this section of the country. The presence of small second-generation larvae in canning corn in Ohio has already necessitated stricter inspection of the raw product during processing at the factory.

## NUMBER OF GENERATIONS

Until recently the European corn borer has had only one principal generation annually in the East North Central States, and over the greater part of the area the insect still adheres to this type of development. Although a very small number of larvae (less than 1 percent) pupated

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in midsummer each year since the discovery of the corn borer near Lake Erie, it was not until 1936 and later that a more appreciable amount of such pupation occurred, particularly in sweet corn, and that a resultant partial second generation was noticeable in certain localities of northwestern Ohio and in northeastern Indiana. The tendency for certain individuals of the borer to produce a second generation in each of the years 1936–39 was widespread in portions of Ohio, Michigan, and Indiana, although the aggregate number of second-generation larvae entering hibernation each fall constituted only a small part of the total population.

A discussion of the second generation of the corn borer in the Lake States in 1936 and 1937 and some of its responses under controlled laboratory conditions has been published by Vance (*15*), and additional information on the subject for the years 1938 and 1939 is given in the present paper. Ficht (*7*, *8*) has dealt with the second generation of the corn borer in Indiana in two recent publications, in the second of which he offers some interesting data on the increasing size of the flight of second-generation moths in that State from 1935 to 1938 and gives a graphic comparison of second- with first-generation flight. According to Ficht (*8*), in the localities in Indiana where the data were taken the number of borer moths of the second generation attracted to light traps in 1938 was much greater than the number of first-generation moths caught. Ficht also found a general trend toward an increased rate of production of two-generation borers in the more southerly part of the insect's distribution in Indiana.

In 1938 first evidence of midsummer pupation of the corn borer near Toledo, Ohio, was obtained July 12 in a field of early sweet corn, and moth emergence began prior to July 26. This phase of the borer's development at Toledo was a week or 10 days earlier in 1938 than in either 1936 or 1937. Field observations indicated that a few borers in 1938 pupated relatively late, one live pupa being found in field corn near Toledo on each of the dates August 22, September 29, and October 1.

Midsummer pupation in 1938 in early sweet corn near Toledo, according to data from random counts of 4,398 individuals in 25 fields procured from July 26 to August 1, averaged 11.3 percent. In 1939 the average pupation found August 1–5 in 25 similar fields in the same locality, in an examination of 2,077 specimens, was 11.8 percent, or practically the same as in 1938. The five fields with the most pupation in 1939 averaged 26.9, 25, 23.1, 21.2, and 20 percent, respectively. On the basis of comparable data, midsummer pupation in 1938 and 1939 was significantly higher than in 1936 or 1937, in which 2 years it averaged 6.2 and 8.7 percent, respectively, in the same locality.

Near Sandusky, Ohio, on August 2–3, 1938, a pupation of 6.3 percent was found among 994 individuals observed in 8 fields of early sweet corn, and 1 pupa, representing 0.5 percent pupation, appeared among 211 borer specimens counted July 28–29, 1938, in 10 fields of early sweet corn near Cleveland, Ohio.

To date, midsummer pupation of the corn borer in Ohio and a subsequent second generation have been less extensive in field corn than in sweet corn. In 1938 live pupae or pupal cases were observed in the course of borer counts in 17 percent of 240 cornfields examined in the northwestern corner of the State during a fall survey of abun-

dance, representing a pupation of 0.9 percent for the 5,521 specimens examined. Similar records in 1939 showed pupation in 5 percent of 125 cornfields in the same section, while pupation among 584 individuals averaged 1.7 percent. In 1939 records of a second generation on the basis of pupae or immature larvae were made in 14, or 23.7 percent, of the 59 counties surveyed in Ohio.

During the fall infestation surveys made in 35 counties of Indiana in 1938 and 1939 records were taken of the number of live pupae and pupal cases encountered among the borers dissected from corn plants in the fields examined.[9] In 1938 some evidence of midsummer pupation was found in 11, or 31.4 percent, of the Indiana counties surveyed, whereas in 1939 it was noted in 22, or 62.9 percent, of the same counties. The amount of midsummer pupation in individual counties in 1938 ranged from 0 to 5.3 percent, and in 1939 it ranged from 0 to 6.9 percent, with an exception of 16 percent in 1 county in 1939. The average pupation for the entire Indiana region in 1938, based on the examination of 2,892 individuals, was 0.7 percent and in 1939, based on the examination of 4,455 individuals, it was 2.6 percent, representing a significant increase from 1938 to 1939. Small borers, presumably of a second generation, were noted in 30.4 percent of the 787 fields surveyed in Indiana in 1938 and in 32.4 percent of the 794 fields surveyed in the same counties of that State in 1939.

Some evidence of a second generation of the borer was found in all 35 counties surveyed in Indiana in 1938 and 1939. The occurrence of 2 generations annually in that State was most pronounced in 11 counties near the eastern edge of the State, in which the percentages of cornfields, in the combined years of 1938 and 1939, containing small or second-generation borers averaged, respectively, 86, 82, 76, 72, 71, 71, 67, 61, 59, 52, and 50. In other words, practically 68 percent of the fields in this group of counties were infested to some extent by a second generation of the European corn borer in the 2-year period 1938–39.

Although various explanations of the recent prominence of two generations of the corn borer in several of the East North Central States could be advanced, the proof in any instance is too inadequate for the drawing of conclusions. Probably the exact causes of the phenomenon will remain obscure, explainable only on more or less theoretical grounds according to the genetics viewpoint adopted as a basis of the speculation. Regardless of this, the fact remains that in Indiana and certain localities in Ohio at least the European corn borer can now be considered a two-generation pest, not particularly different in its reactions and seasonal history from the multiple-generation strain which has been common for years in southeastern New England. Just how extensive and important economically the second generation of the corn borer may become in Ohio, Michigan, and Indiana will be determined by future developments.

## ASSOCIATION OF BORER ABUNDANCE WITH WEATHER

In his discussion of some of the factors responsible for a decrease of the European corn borer in New England during 1923 and 1924,

[9] Data procured in cooperation with the State Conservation Department of Indiana.

Barber (*1*) listed 25 important factors known to have had some influence on seasonal numbers of the insect. This author is probably correct in his belief that the cause of variation in population from year to year is a very involved association of these limiting factors, and no doubt there occurs, as he states, a shifting of their importance from one year to another. At the same time it has seemed possible that one or more of the most influential factors might stand out sufficiently from the rest to serve, in most years at least, as an index which could be associated with changes in abundance of the insect.

Although Babcock (*2*) and Babcock and Vance (*3*) have stressed the influence of weather conditions during the period of hibernation of the European corn borer as especially important in an understanding of annual shifts in abundance of the insect, considerable evidence has been accumulated indicating that the effects of some particular meteorological condition or conditions of the summer season during which the moths are in flight and depositing their eggs and a large proportion of the small larvae are becoming established in the plants have a vital influence on the resulting population of mature larvae.

Ficht (*7*) has stated that weather conditions almost entirely account for fluctuations in borer abundance from year to year and that drought reduces the numbers of the borer and retards spread of the insect, whereas an abundance of moisture and lack of excessive heat favor its increase. He also listed the distribution of rainfall as an important factor in increase and considered gentle rains favorable to the prolongation of the lives of the moths and increase in their output of eggs in contrast to hard, driving rains that might wash off eggs and young larvae during the egg-laying and hatching period.

It has been established by various workers concerned with investigations of the corn borer that the insect needs an abundance of moisture in one form or another in practically all stages of its metamorphosis. In the light of this fundamental knowledge the present study has stressed the association of moisture conditions or precipitation during the growing season with annual increases and decreases of the borer, although temperatures also have been given attention.

The population data procured from 1927–39 in the 18 counties in Michigan and Ohio, given in table 2, were studied in relation to the weather prevailing over the section during that period. Twenty weather stations, each of which had taken records for 10 or more years, were located over the section as designated on the map (fig. 1), and their daily and monthly data on precipitation and temperature as recorded by the Weather Bureau provided quantitative figures on the weather factors. The average daily precipitation was grouped into 5-day periods from May 4 to August 11, inclusive, to permit a closer study of the effects of rainfall, and an attempt was made to associate the abundance of the corn borer with various combinations of the amount and distribution of moisture during different critical parts of the season.

Although the designated section represented the older portion of infested territory in Ohio and Michigan, the borer populations in some of the more western counties of Ohio, particularly in the earlier years of the investigation, had not had sufficient time since initial infestation to build up to the greater and seemingly more stable populations of counties nearer Lake Erie in which the insect had been

longer established. Even with this consideration in mind it should be noted that borer abundance in the western part of the region remained low until near the end of the 13-year period, owing for the most part, it is believed, to a series of seasons in which drought conditions in one form or another were more or less prevalent, and the small numbers of the insect were still sparsely distributed. In addition to being retarded by dry weather in this section, it is probable that the insect encountered certain new environmental complexes unfavorable to immediate increase in its numbers.

From 1927 to 1939, within the section studied, the general trend of corn borer populations was upward, with an increase over the period from 21.3 borers per 100 plants in 1927 to 129.5 in 1938 and 126.5 in 1939. The change in average abundance shown by the figures has not been statistically significant between all successive years, however, and attention is called to the significant annual changes which did take place for the section as a whole (table 5). In 1930 there was a definite decrease of borer abundance from 1929, followed in 1931 by a significant increase. Again, in 1934 the population decreased significantly from 1933, followed in the years 1935 and 1936 by significant increases in infestation, and in 1937 and 1938 by strong trends toward increase.

TABLE 5.—*Annual abundance of the European corn borer and proportionate change in the population from fall to fall in 18 counties of Ohio and Michigan, 1927–39*

| Year | Average borers per 100 plants | Proportionate change | Year | Average borers per 100 plants | Proportionate change |
|---|---|---|---|---|---|
| | *Number* | | | *Number* | |
| 1927 | 21.3 | | 1934 | 15.6 | 0.3 |
| 1928 | 17.1 | 0.8 | 1935 | 42.4 | 2.7 |
| 1929 | 32.7 | 1.9 | 1936 | 69.9 | 1.6 |
| 1930 | 17.3 | .5 | 1937 | 99.0 | 1.4 |
| 1931 | 40.7 | 2.4 | 1938 | 129.5 | 1.3 |
| 1932 | 48.6 | 1.2 | 1939 | 126.5 | 1.0 |
| 1933 | 45.5 | .9 | | | |
| | | | 13 years | 54.3 | |

The population trends are obtainable from the annual averages, but attention should be given also to the proportionate change, as the population in any given year was necessarily influenced not only by attending environmental conditions but by the potential developed in the size of the population in the previous fall. The effect just indicated can be expressed as the ratio of the population of one year to that of the preceding year and this is considered a better criterion of seasonal effects on the borer than the populations themselves. On the basis of these ratios, as given in table 5, the years 1935 and 1931, respectively, were the most favorable for the corn borer, and the years 1934 and 1930, respectively, were the most unfavorable. The other years were intermediate in their effects.

The relationships established between abundance of the corn borer and weather as a result of the studies undertaken were not so definite as was anticipated. Perhaps the weather data available, particularly with reference to precipitation, were not sufficiently detailed to overcome all sampling error. The necessity for a large number of weather samples to allow for the small size and random distribution of

summer convectional storms which, in addition to their importance to growing crops, may have greatly influenced the biology of the corn borer, has been stressed recently by Thornthwaite, Holzman, and Blumenstock (*14, p. 365*). In addition, more detailed data on populations of the corn borer probably would have facilitated the analysis.

It is apparent from the data, however, that extreme drought such as occurred in the section in 1930 and 1934 was very unfavorable to

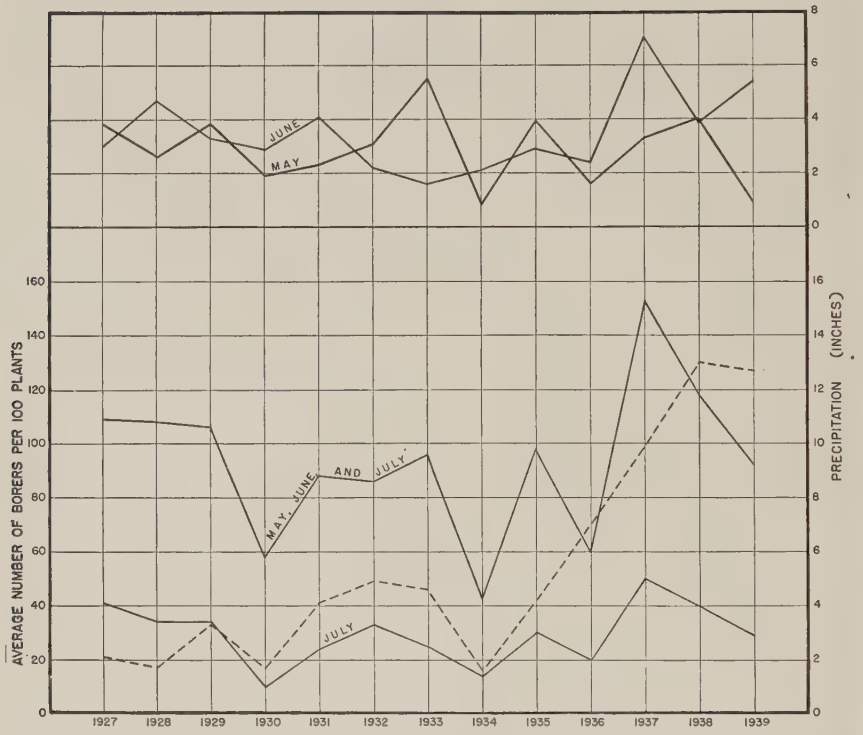


FIGURE 3.—Association of abundance of the European corn borer in a section composed of 18 counties in Ohio and Michigan with precipitation in the months of May, June, and July, averaged for 20 weather stations distributed over the same section, for each of the 13 years 1927 to 1939, inclusive. Populations of the insect are shown by a broken line and precipitation for the designated months by solid lines.

the corn borer and caused significant decreases in populations of the insect. The dryness of the months of May, June, and July in these two years in comparison with the same months in other years studied is indicated in figure 3. Whereas extreme dryness in any or all three of these months was considered adverse to the corn borer, it is probable that drought in July was most detrimental to survival of the insect. Seasonal drought may not only affect the borer directly but, through its influence on the host corn plant, it may also have an indirect but nevertheless important effect in reducing borer survival. Experimentation by other workers has shown that retarded growth or reduced vigor of the corn plants caused by drought or other unfavora-

ble conditions both lessens the amount of oviposition on such plants and lowers the survival of those larvae that do hatch; and when such circumstances complement the more direct effects of drought on the developmental stages of the insect, populations are likely to decline.

During the 1927–39 period studied the nearest approach to the drought conditions of 1930 or 1934 occurred in 1936. It is apparent, however, from the increase in abundance that year, that rainfall was not so low or was not so poorly distributed, in combination with other operative factors, that it produced the same result as in the more extreme drought years of 1930 and 1934. As shown in figure 3, there was much diversity in the rainfall of May, June, and July in the different years studied. The year 1937, one of the years with a trend toward increase, differed from the rest by its exceptionally wet June and July. The years of significant increase, 1931, 1935, and 1936, are not set off strongly by their summer precipitation from years in which the borer population remained more or less static. No significant correlation could be seen between borer abundance and precipitation for any month of the year or for certain strategic periods of the developmental season.

## EFFECT OF WEATHER FACTORS ON DIFFERENT STAGES

The general seasonal development of the one-generation strain of the corn borer in the East North Central States has been discussed by Caffrey and Worthley (*6*), Worthley and Caffrey (*16*), Poos (*12*), and Huber et al. (*10*). Further data on the subject taken in 1926–30 at Monroe, Mich., were published by Bottger and Kent (*5*), and the seasonal history of the insect in Indiana has been outlined by Ficht (*7, 9*).

During the 6-year period 1934–39 an attempt was made to determine and evaluate more definitely the factors responsible for annual fluctuations in the abundance of the European corn borer by studying rather intensively the seasonal development of the insect near Toledo, Ohio, and making observations on the mortality occurring in the different stages. The ultimate objective of the investigation was to obtain a better estimation of the future behavior of the borer both in its present habitat and in areas likely to become infested. These studies provided data of current usefulness, leads for future investigations, and bases for important generalizations concerning seasonal effects on corn borer abundance. On the other hand, they emphasized the complexities involved in relating the reactions of the European corn borer with weather in a way that would permit the assignment of specific weight to definitely described meteorological effects on particular stages of the insect.

### Winter Mortality of Larvae

Worthley and Caffrey (*16, p. 73*), in their evaluation of various clean-up practices, attributed a small percentage of larval reduction, not exceeding 10 percent, to natural mortality from winter killing, parasites, and disease. In the course of field counts it is impossible to isolate accurately the effect produced by any one of the above fac-

tors. Consequently the numbers of dead larvae found each spring, excluding those evidently killed by mechanical means, are considered under the broad term of winter mortality. The average winter mortalities from 1934 to 1938, based on several counts each spring (March, April, May) at different points in Ohio and Michigan, are given in table 6. A very low mortality was found in 1938. Many variations in the amount of winter mortality appeared in the course of spring counts, and in certain fields, owing probably to special conditions of cold and moisture, the mortality figure even exceeded 20 percent.

TABLE 6.—*Winter mortality of the European corn borer in Ohio and Michigan, 1934–38*

| Year | Total specimens examined | Average mortality | Year | Total specimens examined | Average mortality |
|---|---|---|---|---|---|
| | *Number* | *Percent* | | *Number* | *Percent* |
| 1934 | 4,647 | 9.3 | 1937 | 2,350 | 8.3 |
| 1935 | 5,868 | 10.1 | 1938 | 2,225 | 1.4 |
| 1936 | 2,616 | 9.9 | | | |

Unusually low temperatures occurring in the winter of 1933–34 did not increase the mortality of borer larvae excessively beyond that found under more normal conditions, and data taken for a series of years have not shown, on the average, any decided differences in amount of larval mortality attributable to the effect of winter conditions.

Winter mortality in itself, therefore, does not appear to be a factor that can be relied on to explain seasonal fluctuations in abundance of the corn borer. It is probable, nevertheless, that cold weather in its action as an integral part of climate over a period of time has some definite effect in limiting "average populations" or "equilibrium" of the insect in certain regions. Huber et al. (*10, pp. 75–76*) were of the opinion that winter killing was unlikely to be of vital importance in retarding accumulation of the insect in Ohio, and found winter mortality to be under 10 percent in the years 1924–27.

## MORTALITY OF PUPAE

Fewer data are available on the mortality of corn borer pupae in the field than on larvae, owing in the main to the greater difficulty of obtaining sufficiently large samples of pupae in the spring for reliable results.

Pupal mortality in the spring and early summer of 1934 increased considerably among the one-generation individuals of the borer that transformed late in the abnormal heat and drought of July of that year. No great reduction from this cause appeared generally in 1935, although 16.4 percent of the pupae were found dead among 550 specimens examined in Hancock County, Ohio, during the first half of June that year.

In 1936 relatively high pupal mortalities in caged cornstalks were noticed early in July, which led to extended field observations to determine whether similar mortalities were common in the region. Twenty-seven examinations of pupae in 10 counties of Michigan and

Ohio west of Lake Erie were made from July 15 to 21, at which time moth emergence was practically complete, and the data are summarized in table 7. A total of 911 pupae were observed, of which 191, or an average of 21 percent, were dead. Of the 191 dead, 169, or 88 percent, contained dead moths; and of the remaining 22, 10 had apparently been eaten by predators and 12 had become dry prior to the development of the moth. During the period July 8–15, 1936, the temperatures reported at Toledo, Ohio, by the Weather Bureau were minimums of from 73° to 82° F. and maximums of from 99° to 105°. These temperatures, indicative of the intensity of the heat prevailing in the region in which observations were made, were undoubtedly responsible for the high pupal mortality encountered. Similar or more severe heat was common during the same period over a large part of the Lake States area, and consequent high mortalities among pupae were probably widespread that year.

TABLE 7.—*Mortality of pupae of the European corn borer in 10 counties west of Lake Erie in Ohio and Michigan in July 1936*

| Date | Counties | Pupae observed | | |
|---|---|---|---|---|
| | | Emerged and dead | Dead | |
| | | *Number* | *Number* | *Percent* |
| July 15 | Wood and Henry, Ohio | 250 | 71 | 28.4 |
| 16 | Lucas, Ottawa, and Sandusky, Ohio | 200 | 43 | 21.5 |
| 20 | Monroe and Lenawee, Mich., and Fulton and Henry, Ohio | 226 | 32 | 14.2 |
| 21 | Henry, Putnam, Hancock, and Wood, Ohio | 235 | 45 | 19.1 |
| Total | | 911 | 191 | 21.0 |

Possibly the importance of mortality among pupae of the one-generation strain has not been given sufficient consideration, either as a fact in itself or as a reflected influence of weather in affecting fluctuations in seasonal abundance. It is known that hot, dry conditions near Toledo in May and June may result not only in increased pupal mortality but in a prolongation of the normal period during which pupation occurs, and thus may act, to some extent, as limiting factors in the abundance of the borer in the fall of the year in which such conditions occur.

Stirrett (*13, p. 468*) stated that "pupal mortality must be one of the important factors, if not the most important, causing a variation in the number of moths from season to season," and reported that 60 percent of the pupae were killed in one field in Canada in 1934, apparently from excessive heat and lack of moisture.

## FATE OF EGGS

Survival of the European corn borer from the egg to a point of larval establishment within the corn plant is influenced by a number of factors, one of which is the proportion of eggs that escape predators, adverse weather, etc., and can hatch normally. Various authors have mentioned different causes of egg mortality, and recently Stirrett (*13, p. 577*) has listed and discussed them.

Special emphasis was placed on a study of oviposition and larval survival, with detailed observations during 1934, 1935, and 1936, to determine the fate of eggs laid on corn plants in the field. The procedure in any one year was to select 10 cornfields (usually the earliest) for their probable attractiveness to ovipositing moths and to tag 20 plants near the middle of each field. The 200 tagged plants were examined daily throughout the oviposition period in 1934, 1935, and 1936, and at intervals of approximately 3 days in 1937, 1938, and 1939. As a rule the 10 fields were located within a 20-mile radius of Toledo, Ohio.

During this study the most important factors considered to affect the eggs directly were dislodgment by wind or rain or by the curling of the plant leaves by excessive heat, desiccation, parasites, predators, and infertility. Some of the eggs disappeared without leaving evidence of the agent responsible for their destruction. The 3 years' data on the fate of eggs obtained at Toledo, together with supplementary data for a single year from each of the more southern points of Ottawa and Findlay, Ohio, are presented in table 8. The lower egg hatch at both Ottawa and Findlay in comparison with Toledo was accounted for in large part by an increased loss by predators at the first two points. Infertility was less than 1 percent in all cases; relatively few eggs were desiccated, with a maximum of 5.7 percent at Toledo in 1934; parasitization was negligible; and from 0 to 12.7 percent of the eggs were dislodged in some manner. At Toledo, in the years 1934–36, an average of 87 percent of the eggs hatched normally, whereas at Ottawa in 1934 and at Findlay in 1935 approximately 53 and 67 percent of the eggs, respectively, escaped destructive factors and hatched.

TABLE 8.—*Fate of eggs of the European corn borer in selected localities of Ohio in 1934, 1935, and 1936*

| Locality | Year | Total eggs observed | Eggs | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Hatched | Infertile | Desiccated | Parasitized by *Trichogramma* | Destroyed by predators | Dislodged | Missing |
| | | *Number* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* |
| Toledo | 1934 | 857 | 82.0 | 0.0 | 5.7 | 0.0 | 4.2 | 5.9 | 2.2 |
| | 1935 | 3,987 | 75.0 | .5 | 1.8 | .2 | 5.6 | 9.3 | 7.6 |
| | 1936 | 6,287 | 95.4 | .9 | .8 | 0 | .5 | 0 | 2.4 |
| Ottawa | 1934 | 2,425 | 53.2 | .3 | 1.2 | 0 | 17.4 | 0 | 27.9 |
| Findlay | 1935 | 2,498 | 66.8 | .9 | 0 | 0 | 13.8 | 12.7 | 5.8 |

## OCCURRENCE OF OVIPOSITION

The average occurrence of oviposition in the vicinity of Toledo, Ohio, was obtained from a study of data for the 13-year period 1927–39. The average peak of oviposition for this period was July 8–12, and practically three-quarters of the total egg deposition occurred in the 20-day period between June 28 and July 17. In 6 of the 13 years the peak of oviposition occurred July 8–12, in 3 years June 28–July 2, in 2 years June 23–27, in 1 year July 3–7, and in 1 year July 13–17. The earliest years were 1938 and 1939, when 60 and 40.8 percent,

respectively, of the eggs were deposited during the 5-day period June 23–27, and the latest year was 1928, when 61.4 percent of the eggs were laid July 13–17. It should be explained, however, that the data on which the foregoing facts were established were taken for the most part in a locality west of Toledo where considerable early sweet corn is grown and where the presence of two generations of the corn borer has been increasingly pronounced in recent years. Consequently, the earliness of oviposition found in 1938 and 1939 may reflect the influence of these factors as well as the effect of favorable seasonal conditions.

## Size of Egg Masses

The average numbers of eggs per mass at Toledo during each of the years 1930–39 were, respectively, as follows: 15.9, 14.1, 24.2, 17.8, 14, 15.2, 15.4, 15.4, 16.7, and 17.3, or an average of 16.6 for the 10 years of observation. It has not been possible to associate the size of the egg masses with the effect of environmental factors or the physiology of the insect.

## Amount of Oviposition

The deposition of eggs by moths of the European corn borer on representative plants kept under observation in fields of early corn near Toledo, Ohio, in the years 1934 to 1939, inclusive, is shown by 5-day periods and by season in table 9. Following a relatively light oviposition in the dry season of 1934, the number of egg masses per 100 corn plants increased in each of the succeeding 4 years with more normal moisture conditions. In 1938 some eggs were deposited before the beginning of the counts in the period June 18-22, and in 1939 oviposition was slightly less than in 1938.

Table 9.—*Oviposition of the European corn borer in early corn at Toledo, Ohio, 1934–39*

| Five-day period | Egg masses per 100 plants [1] | | | | | |
|---|---|---|---|---|---|---|
| | 1934 | 1935 | 1936 | 1937 | 1938 | 1939 |
| | *Number* | *Number* | *Number* | *Number* | *Number* | *Number* |
| June 13–17 | | | 4 | | | 19 |
| 18–22 | | | 13 | 7 | 56 | 44 |
| 23–27 | 1 | | 19 | 13 | 161 | 98 |
| June 28–July 2 | 11 | 6 | 17 | 26 | 29 | 54 |
| July 3–7 | 10 | 24 | 38 | 21 | 8 | 16 |
| 8–12 | 4 | 62 | 75 | 99 | 13 | 5 |
| 13–17 | 3 | 30 | 37 | 36 | 1 | 4 |
| 18–22 | 2 | 6 | 1 | 12 | | |
| 23–27 | | 3 | | | | |
| Total | 31 | 131 | 204 | 214 | 268 | 240 |

[1] Based on counts taken on 200 plants in selected fields in each of the years considered.

## Summer Larval Survival

Although it is an established fact that the corn borer suffers annually a considerable reduction in population during the critical egg and early larval stages in the field, it is difficult to obtain an accurate survival rate of the insect that would apply equally over any extensive

area. Consequently field data on this subject are relative in nature and cannot be utilized in formulating too broad generalizations.

Attention has been given by various workers to the mortality or loss occurring among young corn borer larvae prior to their definite establishment inside the plant, and there has been rather general agreement that the death rate of the larvae is highest among the first two instars. Stirrett (*13, pp. 581–583, 674*) has summarized the literature on this subject and has added to the effects of wind, rain, and hot, dry periods, mentioned by other workers, a fourth factor which he calls sudden changes in temperature (such as a sudden heat wave) and which he believed to have accounted for most of the larval mortality noted in Ontario, Canada.

Detailed studies on the fate of corn borer larvae have not been undertaken in recent years at Toledo, Ohio. Nevertheless the period during which young larvae are establishing themselves on the corn plant has been recognized as one of the most critical in the seasonal history of the insect. In 1934 and 1935, respectively, at Toledo, 77.2 and 67.5 percent of the total loss during the egg and larval stages was incurred by the young larvae after their hatching. Similar observations have been made in other localities. For example, Caffrey and Worthley (*6, p. 94*) state that close observation during an experiment conducted at Sandusky, Ohio, in 1924 showed that the greatest mortality occurred during the first and second instars, the most important causes of which appeared to be desiccation, starvation, and drowning.

As Stirrett (*13, p. 581*) has pointed out, the tendency often has been to group the actual egg and larval mortalities as one and express the effect in terms of borer survival. This is usually satisfactory, of course, and even necessary unless daily observations have been made to determine just what happened to the eggs.

The percentage of borer survival, from the deposition of eggs to establishment of the young larvae in the plants, was determined for early corn planted near Toledo in the years 1934–38. The survivals for these years were 21.2, 23.1, 27.6, 19.6, and 29.3 percent, respectively, with an average of 24.2. The figure each year was derived from averages of the insect's survival on 20 plants in each of 10 fields and it is believed to be reasonably reliable for the type of corn considered in the locality. There is no doubt, however, that survival in many fields of later corn, and also in less vigorous corn, was much lower than that found in the earlier crops.

In the above 5-year period 49 cornfields were under observation. The average borer survival in these fields was 24.2 percent. Thirty of the fields were of dent corn, in which the survival was 18 percent, with a maximum of 31.8 and a minimum of 6 percent; and 19 of the fields were in early sweet corn, in which the survival averaged 35.4 percent, with a maximum of 67.8 and a minimum of 14.7 percent. Although these figures indicate a higher survival in early sweet than in early dent corn near Toledo, it is possible that differences in maturity of the 2 types of corn were primarily responsible for the variation in survival.

During planting-date tests at Sandusky, Ohio, in 1927 and 1928 Patch (*11*) found significant differences between survival of the borer on the large dent corn varieties Red Cob Ensilage and Leaming (25.6 and 28.4 percent, respectively) and that occurring on the sweet corn

varieties Red Evergreen and Golden Bantam (38.5 and 44.7 percent, respectively). However, similar differences in survival occurred between the above-mentioned dent varieties and the early-maturing variety Northwestern Dent and a variety of flint (35.3 and 38.5 percent, respectively, for the last two). The average percentages of survival on all the varieties were 34 in 1927 and 35.6 in 1928.

## SUMMARY

Since the first finding of the European corn borer (*Pyrausta nubilalis* (Hbn.)) in Ohio and Michigan in 1921, the insect has spread in the East North Central States until by 1939 it was known to infest practically all of Ohio, much of Michigan, the northeastern half of Indiana, several tiers of counties in eastern Wisconsin, five counties in northeastern Illinois, and four counties in northern Kentucky.

Annual fall abundance of the corn borer in comparable territory surveyed in Ohio, Michigan, and Indiana, from 1934 to 1939, inclusive, has ranged from an average low of 12.6 larvae per 100 plants in 1934 to a maximum of 111.2 in 1939.

In a section of Ohio and Michigan comprising 18 counties extending from the western end of Lake Erie the general trend of corn borer populations over the 13-year period 1927-39 has been upward, with an increase from 21.3 borers per 100 plants in 1927 to 126.5 in 1939. Significant decreases in abundance of the insect occurred in the section in 1930 and 1934 and notable increases in 1931 and in each of the years 1935 to 1938. The population in 1939 remained at about the same level as in 1938.

Infestation in early-market sweet corn west of Toledo, Ohio, increased from 1934 to 1938. In the latter year an average of 17.5 borers per plant occurred in this crop, followed in 1939 by a reduction to about half that number.

There was a tendency for certain individuals of the European corn borer to produce two generations in each of the years 1936 to 1939 in portions of Ohio, Michigan, and Indiana, although the aggregate number of second-generation larvae entering hibernation each fall constituted only a small proportion of the total population. Pupation of the first generation in midsummer has been most pronounced in early sweet corn near the western end of Lake Erie in Ohio and in several of the southeastern counties in the infested portion of Indiana.

Attempts to associate abundance of the European corn borer with weather, based on a study of population data taken each fall over the 13-year period 1927–39 in a group of 18 counties in Ohio and Michigan, together with temperature and precipitation records from 20 weather stations distributed over the section, were less fruitful than had been anticipated. The data showed clearly, however, that extreme drought conditions, such as occurred in the section in 1930 and 1934, were very unfavorable to the corn borer and caused significant decreases in populations of the insect. Although unusual dryness in any or all of the months of May, June, and July was considered adverse to the corn borer, it is probable that drought in July was most detrimental to survival of the insect.

Winter mortality, as it occurs within a given environment, is not a factor that can explain seasonal fluctuations of the corn borer. In very hot, dry summers, such as that of 1936 in parts of Ohio and

Michigan, an appreciable mortality may take place among pupae in the field, but in general the egg stage and the period of establishment of the first and second instars in the corn plant constitute two of the most critical phases in the life history of the insect.

Detailed observations on eggs of the corn borer at several points in northwestern Ohio in 1934, 1935, and 1936 showed that less than 1 percent of the eggs were infertile; that relatively few eggs were desiccated, with a maximum of 5.7 percent at Toledo in 1934; that parasitization by *Trichogramma* was negligible; that destruction by predators ranged from 0.5 to 17.4 percent, depending on season and locality; and that up to 12.7 percent of the eggs were dislodged in some unknown manner. From 53.2 to 95.4 percent of the eggs deposited in a given year and locality were unaffected by destructive factors and hatched normally.

In a locality west of Toledo, Ohio, where considerable sweet corn is grown, the average peak of oviposition for the 13-year period 1927–39 was July 8–12. Oviposition was latest in 1928, when 61 percent of the eggs were laid July 13–17, and earliest in 1938 and 1939, when 60 and 41 percent, respectively, of the eggs were deposited during the period June 23–27, reflecting possibly the influence of increased numbers of second-generation borers in the vicinity. The average number of eggs per mass for the 10-year period 1930–39 was 16.6.

Near Toledo, Ohio, in early corn, a relatively light oviposition in 1934, a drought year, was followed by increased egg deposition in each of the succeeding 4 years 1935–38. In 1939 the amount of oviposition was slightly less than in 1938. Survival of borers from the deposition of eggs to establishment of the young borers in early corn in this locality, from 1934 to 1938, averaged about 24 percent.

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